Appendix B – No Action Alternative Complete Report

City of Phoenix
Phoenix, Arizona
Central Arizona Salinity Study

White Paper
On
Future With No Action Alternative

May 2005

Prepared For
City of Phoenix
Water Services Department
Phoenix, Arizona

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Introduction

The primary goals of the Central Arizona Salinity Study (CASS) Phase I were to identify the sources of salinity entering the Central Arizona region, to develop a regional salinity budget to quantify the annual salt loading, assess the potential economic impacts and to recommend the course for Phase II studies. Phase 1 found salinity in the overall water supply has been increasing due to the impacts of drought in the watersheds of the Arizona rivers and the Colorado River, importation and use of Central Arizona Project (CAP) water and due to human activities. The primary goals of Phase II of CASS are to develop and assess alternatives to control or reduce salinity, project the costs and benefits associated with these alternatives and to develop recommendations for implementation. The alternatives in Phase II are all action alternatives because they involve a process or procedure implemented to control or reduce salinity. A Future With No Action Alternative is needed as a baseline to permit assessing the effectiveness of the action alternatives. The purpose of this white paper is to prepare an assessment of the Future With No Action Alternative.

White Paper Summary

CASS Phase I demonstrated approximately 1.3 million tons of minerals, in the form of Total Dissolved Solids (TDS), are imported into the Central Arizona area annually and an additional 0.4 million tons are added by the activities of the residents of the area. In the Phoenix area, approximately 0.5 million tons leave the area but 1 million tons remain. The focus of the Future With No Action Alternative analyses is to identify where these 1 million tons accumulate and to assess potential future impacts. The Future With No Action Alternative assumes no projects will be implemented to control or reduce the TDS in the water sources or the TDS added by the residents.

Principal water sources in the Central Arizona area include surface water, groundwater and reclaimed water. These sources are used to supply the demands of residential, commercial, industrial and agricultural water users. As a part of the identification of potential future salinity impacts, a flow sheet was prepared to track water sources, water use paths, to identify where salinity is increased and to identify where salinity can accumulate. This Salinity Flow Chart is incorporated in the attached Task 100 Memorandum as Figure 1 to provide a foundation to assess future salinity impacts.

The surface water sources in the Phoenix area, include the Salt River, Verde River, Agua Fria River, and Colorado River water imported in the CAP. A review of the historic TDS concentrations verified there is a degree of change in the TDS concentration depending on the conditions in the watersheds; drought, average and surplus or flood conditions. Colorado River TDS measured at Parker Dam averages about 650 milligrams per liter (mg/L) as verified in CASS Phase I. The Federal government has set a TDS limit of 747 mg/L for Colorado River water at Parker Dam. The Agua Fria River is a small quantity water source and changes in TDS concentration will have little impact on the regional TDS. This is because Agua Fria River water is blended with CAP water in Lake Pleasant. The Agua Fria has an average TDS concentration of about 400 mg/L. The Verde River has low TDS concentration, averaging about 270 mg/L. The

Salt River is the surface water source with the greatest potential to have a large variation in TDS concentration. In a median flow year the TDS concentration is about 580 mg/L. During flood periods the TDS decreases to about 500 mg/L; however, during drought periods the TDS has increased to 980 mg/L. Salt River water is blended with both Verde River water and Colorado River water before it is delivered to water users so the full impact of Salt River TDS is diluted by these other water sources. This analysis indicates the degree of TDS concentrations in surface water sources will probably stay within a defined range and will not continually increase or decrease in the future.

The TDS concentration in groundwater varies greatly throughout the Central Arizona area ranging from 200 mg/L to more than 5,000 mg/L in some locations. Reclaimed water TDS concentration depends on the TDS of the wastewater entering the treatment plants.

Figure 1 in the Task 100 memorandum verifies most residential and commercial/industrial water users who are provided surface water and groundwater will subjected to limited increases in TDS in the future. This is because surface water TDS may vary but will not continue to increase and water providers strive to pump groundwater from aquifer zones with TDS concentrations which are equal to or better than the surface water. A second flow sheet, Salinity Impact Calculation Sheet (Figure 2 in the Task 200 memorandum), was prepared for CASS Phase II to calculate the TDS and salinity impacts on a regional basis. This impact projection sheet shows the regional average TDS of water delivered to residential users is about 568 mg/L. If the Salt River TDS concentration increases to 980 mg/L, the calculation projects residential users receive water with a regional average TDS concentration of 663 mg/L. Residential and commercial/industrial water users add TDS the water they receive. It is projected the interior residential and commercial use increases the TDS concentration by an average of 300 mg/L in the wastewater flow. Exterior water is used for landscaping and most of the water is consumptively used by the vegetation. The plants use the water but the majority of the TDS in the water remains in the soil. This results in the accumulation of TDS minerals, commonly called salts, in the soil. Figure 1 in the Task 100 memorandum verified wastewater is a location where TDS concentrations are increased and the soil horizons are where salts can accumulate. Over a long period of time some of the salts accumulating in the soils beneath residential and commercial/industrial areas may percolate down and impact the TDS concentration in groundwater. However, when the land area currently used for residential and commercial/industrial purposes is compared to the potential salts accumulation in the soils, the potential soil salt accumulation impacts spread over a very large area and may not represent an immediate concern.

Figure 1 in the Task 100 memorandum shows agricultural water uses receive surface water, groundwater and reclaimed water for irrigation. The majority of the irrigation water is consumptively used by the vegetation but unlike residential exterior water users, farmers apply additional water to leach the salts accumulating in the soil. This leaching water carries the salts down below the root zones of the plants and often down into the aquifer units where the leaching water can increase the TDS of the groundwater. Task 100 Figure 1 shows when the groundwater is pumped for irrigation, this cycle of irrigation, leaching and pumping can have long term impacts increasing the groundwater TDS concentration. However, the potential long-term impacts to commercial agriculture may not be significant. Many farmers such as in the Buckeye Irrigation District west of Phoenix use water with high TDS concentrations for irrigation. They need a greater quantity of water for leaching to grow their crops when compared to other areas but they are able to use the poorer quality water. The Salinity Impact Calculation Sheet (Task 200 Figure 2) shows the regional irrigation water TDS is 1,064 mg/L and this includes a groundwater TDS of 2,100 mg/L to acknowledge the use of poor quality groundwater by farmers. If the Colorado River water increases to 747 mg/L, the impact on the regional irrigation water supply changes the TDS to 1,079 mg/L. If the Salt River increases to 980 mg/L the irrigation supply TDS increases to 1,125 mg/L. While this does represent an increase, the 1,125 mg/L represents a lower TDS concentration than some of the reclaimed water used for irrigation. The long term regional impacts associated with agricultural irrigation include TDS increases in groundwater due to the leaching practices. Another factor to consider is the agricultural impacts on groundwater have been decreasing and will continue to decrease as farmland is urbanized.

Reclaimed water is a TDS accumulation point where there may be impacts in the future. Residential and commercial/industrial water users add TDS to the wastewater impacting the quality of the reclaimed water produced at treatment plants. Figure 1 in the Task 100 memorandum shows reclaimed water is used for agricultural irrigation, turf irrigation at facilities such as golf courses and for groundwater recharge. Several of the reclaimed water facilities in the Phoenix are produce reclaimed water with average TDS concentrations ranging from about 900 to 1,100 mg/L. Seasonal water use and water supply impact can result in the production of reclaimed water with TDS concentrations of 1,400 mg/L. As previously stated, this water is used by farmers for agricultural irrigation without significant impacts. The potential problems are associated with turf irrigation and groundwater recharge.

Most golf courses want water with a TDS concentration less than 1,200 mg/L to avoid salinity damage to the turf. When the TDS approaches 1,200 or exceeds this concentration the turf begins to turn yellow and is more susceptible to disease. Water use on golf courses is strictly controlled by the Arizona Department of Water Resources management plan goals, so golf course operators can not simply increase the water application to leach the additional salts below the turf root zone. This means the salts can accumulate in the soil. However, unlike the residential soil salt impacts, the local impacts at golf courses can be significant over time because of the greater quantity of water used and the greater total volume of salts remaining in the soil. The potential future impacts to turf applications associated with no action assessment is as the TDS of water supplies increases the water may no longer meet the intended use. A future scenario associated with this condition is water from other sources may need to be diverted for golf course water use. The increased TDS concentration in reclaimed water then becomes a water resources supply issue rather than just a water quality issue.

Reclaimed water used for groundwater recharge may be impacted if the TDS concentration in reclaimed water continues to increase. In some areas where there is groundwater with high TDS, the impacts of reclaimed water may improve the groundwater. In portions of the Central Arizona area, reclaimed water with concentrations of 1,000 mg/l may not be suitable for groundwater recharge because it will have a negative impact on the groundwater quality. In the Tucson area, Colorado River water has a greater TDS concentration than the groundwater and via recharge it impacts the groundwater quality. If reclaimed water TDS concentrations increase in the future it may not meet the standards established for groundwater recharge. Just as with the direct use on turf, the TDS issue then becomes a water resources issue rather than just a water quality issue.

The analyses show the TDS can accumulate as salts in the soils and increase the TDS concentration in reclaimed water and groundwater. Salts in the soil and in reclaimed water will have very little impact on water used for potable supplies, under the current regulatory environment. Regulations may also prevent reclaimed water with high TDS concentrations from being used for groundwater recharge. The accumulation in the soil and in water supplies used for irrigation represents the area where the impacts can be projected.

The suitability of water for irrigation is not based solely on the TDS concentration of the water supply. It is also based on the salinity of the soil and the salt tolerance of the plants. The salinity of the water is expressed at TDS and in agricultural studies it is referred to as the electroconductivity of the water (ECw) expressed as millimohos per centimeter but can be equated with TDS mg/L concentrations. When considering the impacts of salinity in irrigation water to plants, less than 480 mg/L is not considered to be a problem. Water with a TDS concentration between 480 and 1,920 mg/L represents moderate problems meaning plant growth and crop yield is negatively impacted and the amount of impact is also dependant on the plant sensitivity. Water with a TDS concentration greater than 1,920 mg/L is considered to present severe problems to plants. Most of the surface water used in Central Arizona is in the lower portion of the moderate problem range (Figure 3) in Task 200 memorandum). Groundwater can be in the sever problem range. Most of the reclaimed water produced in the Phoenix area is in the middle portion of the moderate problem range (Figure 4) in the Task 200 memorandum).

Water is only part of the consideration. Soil salinity is the other major factor. Soil salinity is measured by calculating the electroconductivity of the soil saturation extract (ECe), the fluid obtained from saturated soil. This is measured in the laboratory. Using the Phoenix area as an example, most of the soils have an average ECe of 1 to 4 and a maximum of 8. There are some soils with an average ECe of 4 to 8 and a maximum of 60. The following table shows the plant response to soil ECe.

ECe mmhos/cm measurement	Plant response
0 to 2	Mostly negligible
2 to 4	Growth of sensitive plants may be restricted
4 to 8	Growth of many plants restricted
8 to 16	Only tolerant plants can grow satisfactorily
Greater than 16	Only a few, very tolerant plants grow satisfactorily

Soil Salinity Plant Impacts

If the salinity in soil increases, the ECe increases and this will impact the growth of crops, turf and landscaping plants. The degree of potential impact is dependent on the ECe of the soil, the TDS of the irrigation water which impacts the volume of salts accumulating in the soil, the TDS of the irrigation water considering the suitability for irrigation use (ECw) and the salt tolerance of the plants. In areas with low ECe soils and low ECw irrigation water, the potential impacts may not be detected for decades. In areas with higher ECe soils and high ECw water such as reclaimed water, the impacts may be detected in less than a decade. If no salinity controls are implemented the water may not be suitable for landscape or turf use.

The Future With No Action Alternative analyses verified the water sources most likely to be impacted in the future due to increases in TDS concentrations are reclaimed water and groundwater. The TDS in these water sources may increase to the concentration where they are not suitable for some uses. TDS concentration increases in the water may produce impacts which are easier to quantify and the impacts may be detected in a shorter period of time than the accumulation of salts in the soils. Increasing TDS concentrations may have long term water quality impacts but may also have an impact on the overall quantity of water resources available in Central Arizona if some water supplies are no longer suitable for the intended direct and indirect uses.

Task 100 Impact Identification and Research

Memorandum

Date: May 10, 2005
To: CASS Planning Technical Committee
From: Frank Turek
Re: Central Arizona Salinity Study Phase II
Project No. WS90120017
Future With No Action Alternative White Paper
Task 100 – Impact Identification and Research

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The purposes of this memorandum are to:

- Summarize the results of the research completed as a part of Task 100
- Document the potential total dissolved solids concentrations in selected water sources
- Prepare an initial list of potential future impacts

In this memorandum, the term salinity is used to describe the regional condition of the accumulation of dissolved minerals. Total dissolved solids (TDS) is used when references are made to concentration changes in water and soil.

1.0 Research

The principal documents researched as a part of Task 100 were the Central Arizona Salinity Study (CASS) Phase I Final Report and the Technical Appendix reports. Additional information sources reviewed and cited are listed in the 4.0 References Cited section. Information collected by telephone is also cited in the text.

2.0 Salinity in selected water sources

The Scope of Services identified three locations where the TDS in the water sources should be verified. These locations are:

- The average TDS of Central Arizona Project (CAP) water at Lake Havasu as calculated in CASS Phase I
- The Colorado River Basin Salinity Control Forum salinity goal at Lake Havasu
- The Salt River TDS based on drought, normal and surplus flow conditions

2.1 Average TDS in CAP water

The CASS study team reviewed historic TDS concentrations in Lake Havasu and in the CAP and calculated the average TDS concentration. CASS Phase I Final Report (Bur. Rec. 2003) reported the average CAP TDS concentration is 650 milligrams per liter (mg/L).

2.2 Colorado River Salinity Goal at Lake Havasu

The Environmental Protection Agency in 1972 required the development of numeric salinity control standards for the Colorado River. The standards were proposed in 1974 and adopted by all the basin states in 1975. The TDS standard for Lake Havasu, measured at the U.S. Geologic Gaging Station below Parker Dam is 747 mg/L. CAP water TDS concentration is less than this standard. In Water Year 2002, the TDS concentration at the Parker Dam gaging station ranged from a low of 591 mg/L to a high of 613 mg/L and this was a drought year when the TDS concentration is expected to be greater than average.

2.3 Salt River salinity

The salinity of the Salt River varies due to the quantity of flow entering the Salt River and Verde River reservoir system; however, the principal impacts are related to flow in the Salt River. CASS Phase I evaluated the average salinity of the Salt River, measured at Stewart Mountain Dam and calculated an average TDS concentration of 580 mg/L (Bur. Rec., 2003). Steward Mountain Dam is a location upstream of where the Verde River joins the Salt River and is upstream of Granite Reef Diversion dam where CAP water is added to the combined flow of the Salt and Verde Rivers.

Dr. Gregg Elliot at SRP was contacted to verify the average TDS concentration of the Salt River at Stewart Mountain Dam in a high flow year and drought year. Dr. Elliott reported the TDS was about 500 mg/L in 1993 which was a high flow year and was about 980 mg/L in 2002 which was a drought year.

3.0 Potential Future Salinity Impacts

3.1 Water Use and Salinity Flow Chart

The initial step in the identification of potential future salinity impacts was to develop a flow sheet to track water sources, water use paths, identify where salinity is increased and identify where salinity can accumulate. Figure 1 is a graphic representation of this information.

Surface water sources include the Salt, Verde, Agua Fria, Gila and Colorado Rivers. Surface water sources will have changes in the TDS concentration due to seasonal flow fluctuations, blending, flood conditions and the impacts of drought. However, the long term salinity of surface water sources will be relatively constant.

Groundwater TDS concentrations vary throughout the Central Arizona area. TDS concentration of groundwater can be in the range of 250 mg/L to more than 3,000 mg/L. This is a much greater variation than occurs in surface water. The groundwater TDS concentration differences are due to the hydrogeologic conditions in the area and the impacts of land uses. This is explained in greater detail in the section 3.6 Groundwater Recharge.

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3.2 Residential Water Use

Residential water use is divided into exterior and interior uses and is supplied by surface water and groundwater as shown on Figure 1. The proportion of surface water and groundwater supplied to a residential area does vary; however, both water sources are appropriate for potable water use. Reclaimed water is not delivered for residential use.

3.2.1 Exterior Residential Water Use

Most of the exterior residential water use is for landscape irrigation including turf and evapotranspiration concentrates TDS in the soils at or near the surface. Commercial agriculture irrigation includes a volume of water for leaching to flush the TDS down through the root zone and, in many cases, to the groundwater table. Residential irrigation uses less water and does not include a planned volume for leaching. Therefore, the TDS will accumulate in the soil. As the TDS concentration in the soil increases, the turf can yellow. Rainstorms can provide a dilution of TDS in the soil and leach the TDS to a depth below the root zone but usually there is not sufficient rainwater infiltration to cause the TDS to percolate to the groundwater table. Rainstorms can result in a reversal of the yellowing trend and produce green turf. During a drought and between rainstorms, many homeowners may increase the irrigation application and apply fertilizers in an attempt to get the turf to turn green again. Fertilizers add salinity to the soils and can increase soil salinity problem. In CASS Phase I, it was projected fertilizers used on lawns add 245 pounds of salinity per acre of lawn per year (CASS Phase I Appendix R, 2003). Some homeowners may use more water for irrigation and have increasing water bills. Regionally, the water use impacts of increasing irrigation to compensate for soil salinity may be offset due by conservation as other homeowners replace turf with xeriscape vegetation.

Figure 1 shows exterior residential water use results in salinity accumulating in the soil and soil represents a terminal salinity storage location. Soil salinity is a regional condition as the urbanized areas expand and turf irrigation continues. Residential exterior water use will not produce local high concentrations of salinity but the long term, regional impact will result in significant tonnage of salinity accumulating over wide areas. As urbanization continues throughout Central Arizona, salinity will continue to accumulate in the soil expanding the potential area of impacts.

The future with no action assumes there will be no control or reduction of TDS in water used for exterior residential purposes and salinity will continue to accumulate in the soil. The exterior residential water use impacts associated with salinity buildup in the soils are:

- Soils will become a reservoir or sink for accumulating TDS
- Landscape water use may increase due to increased water needs to flush salinity below the root zone

- Individual homeowner costs may result due to increased water use and fertilizer use

3.2.2 Interior Residential Water Use

Interior water use is where there are increases the salinity in the wastewater discharges from the homes as shown on Figure 1. There is an estimated TDS increase of 300 mg/L associated with interior residential water use (Bur. Rec., 2003). A part of this increase is due to the use of residential water treatment units. Many homeowners have installed water treatment units and many homebuilders now include water treatment units when the home is constructed. In areas where there are a high number of home water treatment units, the TDS increase may be as great as 400 mg/L (Kelso, oral communication, 2004).

Demineralization water treatment units, such as reverse osmosis (RO) units, remove TDS from the water. Most residential RO units produce about one to nine gallons of concentrate for each gallon of treated water (Plumberspage, 2004) and some units can waste 90 gallons of concentrate to produce 5 gallons of purified water (North Dakota State University, 1992). The concentrate is a concentrate including the minerals removed from the treated water produced by the unit. Fortunately, most residential RO units are small and the quantity of water consumed and concentrate produced is limited. RO units do not increase the overall TDS load in the wastewater but they can increase the concentration. The TDS load is not increased because the RO units do not add minerals during the treatment process. RO units produce concentrate water when water is consumed, primarily during times corresponding with when people are awake. This is also when the wastewater flows in the sewers are high and can dilute the small TDS concentration increases. Wastewater treatment plants (WWTP) and water reclamation plants (WRP) are usually not impacted by the use of RO units because the overall salinity load to the plant is not changed.

Many homes contain water softeners increase the TDS load and concentration. Ion exchange units substitute sodium or potassium ions for calcium and magnesium ions in the water. The TDS in the softened water is for all practical purposes the same as the input water. However, the ion substitution results in an increase in the TDS load because the calcium ions are discharged to the sewer when the softeners are regenerated. This increases the overall TDS load to the WWTPs and can impact the quality of the reclaimed water produced by the WWTPs as discussed in section 3.5 Reclaimed Water. Ion exchange water softeners can have a significant impact on the TDS concentration in wastewater because most units are set to regenerate at night and the regeneration delivers a concentrated stream of high TDS water to the sewer. Because this regeneration occurs at night when the wastewater flows are low, the impact of ion exchange regeneration discharges can have a significant impact on the concentration of the wastewater entering WWTPs. The overall load to the sewer system would be the same if the regeneration occurs during the day or night but there is a difference in the concentration due to the potential dilution in the sewers.

Figure 1 shows the wastewater from interior residential water use flows to WWTPs and WRPs for treatment and production of reclaimed water for reuse.

The future with no action assumes there will be no reduction of the TDS in the water supply for interior residential use. The interior residential water use potential salinity impacts are:

- Slightly increased water consumption associated with the operation of residential water treatment units
- Increased TDS in the residential wastewater
- Potentially greater sewer treatment bills due to the salinity impacts at WWTPs and WRPs

3.3 Commercial and Industrial Use

Commercial and industrial sites can be provided with surface water, groundwater and reclaimed water as illustrated on Figure 1. This use category also includes residential uses such as schools, public buildings and hospitals.

3.3.1 Process Water

Surface water, groundwater and reclaimed water are all included in the process water supply. In some commercial operations, such as the food industry, only surface water and groundwater is appropriate for use. In other operations, the use of all three water sources is appropriate.

Some of the process water is consumptively used but the remainder is usually discharged to the sewer where it flows to WWTPs and WRPs for treatment as shown on Figure 1. Many of the commercial and industrial process water uses increase the TDS load and concentration. Industrial processes can add minerals to the water increasing the load. Some industries purify the water using demineralization and this increases the TDS due to the concentrate stream discharge.

Process water is also used in cooling towers (for purposes other than air conditioning) and this concentrates the TDS. Industrial cooling tower uses increases the concentration of TDS discharged to the sewer but not the load.

Surface water and groundwater from the potable water system will not have significant impacts on the use for process water. Potable water must meet specific standards and public acceptance criteria. The TDS concentration may vary throughout the year but should remain within acceptable water quality and palatability standards. Groundwater pumped directly from wells to the commercial and industrial site and reclaimed water may be subjected to regional salinity increase impacts. Seasonal variations in the salinity in water sources, treatment costs and the disposal of TDS concentrate have a significant impact on the cost of process water and the feasibility for an industry to locate in an area served by water with high salinity (TNT, 2003).

If the salinity of the groundwater from local wells and reclaimed water increases to a concentration where it is no longer suitable for the intended process water purposes, then the commercial and industrial water user may need to use water from the potable water system to meet their demand. This will increase the water demand placed on the water provider and could result in increased water costs as water providers develop additional water sources to meet the increasing demands. The other option is to provide additional treatment to reduce the TDS in the process water.

Process water use can increase the TDS load and concentration in the final water which is discharged to the sewers where the impacts are seen at the WWTPs and WRPs.

The future with no action assumes there will be no control or reduction in the TDS in surface water, groundwater or reclaimed water supplies delivered for commercial and industrial process water. Commercial and industrial process water potential salinity impacts are:

- Increased water treatment costs
- Reduced suitability of water sources for process water use
- Potentially greater sewer treatment bills due to the salinity impacts at WWTPs and WRPs

3.3.2 Exterior Commercial and Industrial Use

Exterior commercial and industrial water use focuses on irrigation using surface water, groundwater and reclaimed water supplies as shown on Figure 1. The salinity of commercial and industrial irrigation mirrors the impacts associated with residential exterior water use, the accumulation of TDS in the soil.

Salinity accumulation will continue as the urbanized areas with commercial and industrial landscape irrigation expands. Commercial and industrial exterior water use will not produce local high concentrations of salinity. Soil TDS is a terminal salinity storage location. The long term, regional impact will result in the accumulation of salinity over wide areas on an annual basis.

The future with no action assumes there will be no control or reduction in TDS in water used for exterior commercial and industrial purposes and salinity will continue to accumulate in the soil. The exterior commercial and industrial water use potential impacts associated with increasing salinity buildup in the soils are:

- Soils will become a reservoir or sink for accumulating TDS
- Landscape water use may increase due to increased water needs to flush salinity below the root zone
- Additional costs may result due to increased water use and fertilizer use

3.3.3 Commercial and Industrial Environmental Use

The commercial and industrial environmental use includes the water used for cooling and for other public uses. Figure 1 shows the water sources include surface water and groundwater from the potable water system. Cooling tower water concentrates the salinity and discharges to the sewer, in most cases. Rest room water and other uses similar to interior residential water use, results in discharges to the sewers. Many commercial and industrial sites use local water treatment systems to enhance the palatability of the water. Just as with the residential units, these on-site water treatment units increase the salinity concentration and load in the wastewater.

The future with no action assumes there will be no control or reduction of the TDS in the water supply for commercial and environmental use. The commercial and industrial water use potential salinity impacts are:

- Slightly increased water consumption associated with the operation of on-site water treatment units
- Increased TDS in the wastewater discharge
- Potentially greater sewer treatment bills due to the salinity impacts at WWTPs and WRPs

3.4 Irrigation Use

Figure 1 shows surface water, groundwater and reclaimed water are used for irrigation and irrigation is divided into three general categories:

- Commercial agriculture
- Golf course irrigation
- General turf irrigation

3.4.1 Commercial agriculture

Commercial farming can tolerate a wide range of salinity in irrigation water depending on the salinity tolerance of the crop and the soil conditions. Most farmers include a quantity of water in their irrigation supply for flushing the TDS accumulating in the soil below the root zone of the plants. This is called leaching water and TDS is concentrated in the leaching water. It was calculated in CASS Phase I, an irrigation water source with a TDS of 700 mg/L could result in a leaching water TDS concentration of 4,200 mg/L (CASS Phase I, Appendix P, 2003). Figure 1 shows this leaching water will eventually percolate down to the water table and will impact groundwater. This condition has been well documented throughout Central Arizona in agricultural areas. TDS is not the only chemical component impacting groundwater, fertilizers, pesticides and other agricultural chemicals have been transported to the water table with the leaching water.

In the past, commercial agriculture was far more extensive than it is currently. In the future as urbanization continues, additional land will be converted from farming to other land uses. This means the quantity of leaching water percolating to the aquifer will be reduced. However, commercial agriculture has been on-going in Central Arizona since about the 1860s and the leaching water has impacted the groundwater. In some locations, the full impact of leaching water has not yet occurred because the leaching water percolates slowly to the water table. There may be a volume of leaching water still moving down and this leaching water will continue to percolate even after the farmland is urbanized.

Salinity associated with commercial agriculture can result in an accumulation of TDS in the soil but due to leaching, the majority of the TDS will impact the groundwater. The accumulation of TDS in the groundwater is not a terminal accumulation point because continued groundwater pumping recycles the TDS as shown in Figure 1.

The future with no action assumes there will be no control or reduction of the TDS in the surface water, groundwater and reclaimed water supplies for commercial agriculture. The commercial agriculture use potential salinity impacts are:

- Increasing TDS in the groundwater supply beneath commercial agriculture areas
- Changing the cropping pattern to use more salinity tolerant crops if the groundwater quality degrades. This could increase farming costs and decrease the per acre profit as crops are changed.

3.4.2 Golf Course Irrigation

Golf course irrigation is a commercial irrigation water use regulated by the Arizona Department of Water Resources (ADWR). These regulations encourage the use of reclaimed water but as shown on Figure 1, surface water, groundwater and reclaimed water are all used for irrigation. The hybrid turf grass species are not very salinity tolerant. Research has shown when the TDS concentration exceed 650 mg/L the grow-in after winter over seeding was slowed and when the TDS exceeds 1,000 mg/L the effectiveness of fertilizers is reduced (CASS Phase I, Appendix L, 2003).

The principal salinity impact is tied to reclaimed water and groundwater used for turf irrigation. The addition of TDS to the sewer system increases the TDS concentration in the reclaimed water provided to golf courses. Groundwater pumped from aquifer units with high TDS concentrations will also impact golf course operations. The hybrid turf grasses become stressed and turn yellow and the salinity accumulates in the soil.

Golf course managers can apply for a leaching allotment to supplement their irrigation supply and ADWR can approve the allotment after reviewing information on the soil conditions and the TDS of the irrigation water. The leaching allotment is usually sufficient to flush the TDS from the root zone of the turf but is not sufficient to flush the TDS to the groundwater table. This means golf courses can result in the long term accumulation of TDS in the soil horizons.

The future with no action assumes there will be no control or reduction in TDS in water used for golf course irrigation and salinity will continue to accumulate in the soil. The golf course water use potential impacts associated with increasing salinity buildup in the soils are:

- Soils will become a reservoir or sink for accumulating TDS
- Water use may increase due to an allotment of leaching water for turf irrigation
- Additional golf course operation costs may result due to increased water use and fertilizer use

3.4.3 General Turf Irrigation

General turf irrigation includes uses for parks, cemeteries and school fields. Irrigation water quantities for this irrigation are also regulated by ADWR. Surface water, groundwater and reclaimed water can all be used for general turf irrigation and the principal salinity impact is the accumulation of TDS in the soil as shown on Figure 1. Bermuda grass normally used for general turf applications has a greater salinity tolerance than the hybrid grasses used on the greens and tees at golf courses. However, the water allocation for leaching is limited and TDS will accumulate in the soils rather than percolating to the groundwater table. The soils represent a terminal point where TDS accumulates. General turf irrigation will not produce local high concentrations of salinity.

The future with no action assumes there will be no control or reduction in TDS in water used for general turf irrigation and salinity will continue to accumulate in the soil. The general turf water use potential impacts associated with increasing salinity buildup in the soils are:

- Soils will become a reservoir or sink for accumulating TDS
- Water use may increase due to an allotment of leaching water for turf irrigation

3.5 Reclaimed Water

Discharges from residential areas and from commercial and industrial uses are conveyed through the sewer system to WWTPs and WRPs where the water is treated and reclaimed water produced. Reclaimed water can be used directly for irrigation and for commercial and industrial purposes as shown on Figure 1 or it can be used indirectly via groundwater recharge and later recovery. Most of the reclaimed water produced in Central Arizona can be used without additional treatment to reduce the salinity. However, there is a concern as salinity increases in the discharges to the sewers; the salinity of the reclaimed water may increase to a concentration where it no longer is appropriate for some direct or indirect uses. Advanced water treatment may be required to reduce the salinity of the reclaimed water.

Figure 1 shows high salinity reclaimed water going through additional treatment to reduce the TDS. The product water can be used for the same reclaimed water direct and indirect uses. The concentrate streams can go to disposal or, in some cases, is discharged to the sewer where it eventually gets back to WWTPs and WRPs, further impacting the TDS of reclaimed water.

An alternative to recover additional quantities of reclaimed water is to provide additional demineralization treatment to remove TDS from the concentrate stream. The product water from this additional treatment can be used for reclaimed water direct and indirect purposes and the concentrate stream will go to disposal. Disposal represents a terminal point where salinity can accumulate in landfills, evaporation ponds and potentially, can be beneficially used by selected industries.

The future with no action assumes there will be no control or reduction in TDS in wastewater used to produce reclaimed water and salinity will continue to increase in the reclaimed water supply. The potential impacts associated with increasing salinity in the reclaimed water supply are:

- Reclaimed water may not meet the quality requirements for direct use
- Reclaimed water may not be appropriate for groundwater recharge in some locations
- Additional water sources may be needed to replace the reclaimed water
- Water rates may increase as water provides develop additional water sources to meet the increasing demands
- Potentially greater sewer treatment bills due to the salinity impacts at WWTPs and WRPs

3.6 Groundwater Recharge

Figure 1 shows both surface water and reclaimed water are used for groundwater recharge. While the TDS of the surface water is relatively constant, reclaimed water TDS can vary and this may have an impact on the average quality of the groundwater in the zone of hydrologic impact. In Central Arizona, the TDS of the groundwater varies from about 200 mg/L to an extreme of about 40,000 mg/L. In some locations the quality of the recharged reclaimed water may have a negative impact on the average groundwater quality and in other locations the recharge may enhance the groundwater quality.

Figure 1 shows in some cases pumped groundwater, consisting of groundwater in storage and both natural and artificial recharge, is suitable for delivery in the public water system and can be used for commercial and industrial uses as well as for irrigation. If the groundwater quality is poor, treatment may be needed to enhance the quality so it meets standards and public acceptance. Some poor quality groundwater may not meet public acceptance criteria but can be directly used for irrigation.

Treatment to reduce the TDS of poor quality groundwater produces product water which can be added to the overall groundwater supply and used for the same purposes as good quality groundwater as shown on Figure 1. The concentrate is either discharged to the sewer where it can exacerbate the reclaimed water salinity problem or sent to disposal facilities. Discharging the concentrate to the sewer moves the TDS problem from the groundwater reservoir to the reclaimed water system. Disposal is a terminal accumulation point for salinity.

In some cases, it will be feasible to provide additional demineralization treatment of the concentrate stream to recover additional water. The product water can be added to the overall groundwater supply and used for the same purposes as good quality groundwater. The concentrate will go to disposal.

The future with no action assumes there will be no control or reduction in TDS in reclaimed water used for groundwater recharge and salinity may increase in the groundwater in some areas. The potential impacts associated with increasing salinity in the groundwater supply due to recharge are:

- Increasing salinity in the aquifers
- Groundwater quality degrading until it can not be used for the intended purposes
- Prohibition of using some reclaimed water for groundwater recharge
- Increasing cost to those who want to treat high TDS groundwater for specific uses such as potable water or irrigation

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PBS&J

Task 200 Assessment of Impacts

Memorandum

Date: May 13, 2005
To: CASS Planning Technical Committee
From: Frank Turek
Re: Central Arizona Salinity Study Phase II
Project No. WS90120017
Future With No Action Alternative White Paper
Task 200 – Assessment of Impacts

The purposes of this memorandum are to:

- Summarize the results of the research completed as a part of Task 200.
- Develop a list of TDS concentration limits associated with water uses.
- Project the impacts associated with salinity increases in the soil horizons.
- Identify the magnitude of changes which may occur in the surface water, groundwater and reclaimed water supplies.
- Compare the salinity tolerance limits associated with the uses to the projected water supplies to project when the supply may not be suitable to meet the intended uses.

In this memorandum, the term salinity is used to describe the regional condition of the accumulation of dissolved minerals. Total dissolved solids (TDS) is used when references are made to concentration changes in the salinity of water sources. Soil salinity changes are described in terms of loading such as tons of accumulation and the electrical conductivity of the soil extract (ECe).

1.0 Research

The principal documents researched as a part of Task 200 were the Central Arizona Salinity Study (CASS) Phase I Final Report and the Technical Appendix reports. Additional information sources are listed in the 10.0 References Cited section. Information collected by telephone is also cited in the text.

2.0 Water Use and Salinity Flow Chart

As a part of the identification of potential future salinity impacts, a flow sheet to track water sources, water use paths, to identify where salinity is increased and to identify where salinity can accumulate was prepared in Task 100. This Salinity Flow Chart is incorporated as Figure 1 to provide a foundation to assess future salinity impacts.

3.0 Salinity Load Flow Chart

As a companion to Figure 1 a Salinity Load Flow Chart is included as Figure 2 in this Task 200 memorandum. The Salinity Load Flow Chart was prepared in conjunction with the CASS Phase II Planning Technical Committee efforts. Figure 2 is a graphic representation of the average year salinity conditions in the Phoenix Active Management Area (Phoenix AMA) and shows the salinity loading impacts in water sources, water uses and where salinity is accumulating. The Phoenix AMA Salinity Load Flow Chart is used in this memorandum because the Phoenix AMA has the most complex water sources mixture and salinity discharges. The Salinity Load Flow Chart is based on the salinity balance developed in CASS and the information presented in Figure 1 Salinity Flow Chart.

The Salinity Load Flow Chart is a two part modeling spreadsheet. The first worksheet is the data input section to the model. This allows the quantity and TDS associated with the water sources to be adjusted to project future conditions. It also allows for adjustment of the water use data. A copy of the data input worksheet is included as Figure 3. The model input information is used in the Salinity Load Flow Chart worksheet to calculate TDS concentration changes and the salinity loading, accumulation and discharge impacts. These changes impact the water sources, water supplies and water uses.

The Salinity Load Flow Chart is used in the Task 200 memorandum to project the future impacts associated which may occur in the future if no action is undertaken to control or reduce the salinity.

4.0 Salinity in Water Sources

There are three primary sources of water in Central Arizona; surface water, groundwater and reclaimed water which includes both secondary and tertiary treated municipal effluent. Each source meets the demands of several uses and some sources are not suitable for specific uses. An example is reclaimed water is not generally provided for residential use. In Tucson, some residential customers receive reclaimed water for non-potable use. The numbers are currently small but will increase significantly over time. Groundwater with a high TDS concentration is also not provided for residential use. Prior to assessing future salinity impacts it is necessary to project the TDS concentrations and salinity loading associated with the water sources. A purpose of Task 200 is to identify the magnitude of changes which may occur in the surface water, groundwater and reclaimed water supplies. The following subsections identify and quantify the TDS and salinity load changes.

4.1 Surface Water

Surface water is used in public water supply systems to meet residential, commercial and industrial demands, for agricultural, turf and golf course irrigation and for artificial recharge of groundwater. This is shown on Figures 1 and 2. The surface water sources available for use in Central Arizona include:

- Colorado River via the Central Arizona Project (CAP) which is used in the Phoenix AMA, Pinal AMA and Tucson AMA.
- Agua Fria River water is blended with CAP water in Lake Pleasant and thus, physically is used in the same Central Arizona areas as is CAP water but all water rights associated with the Agua Fria River are dedicated for use in the Phoenix AMA.
- Salt River water is used in the Phoenix AMA
- Verde River water is used in the Phoenix AMA.

Surface water sources will vary in the TDS concentration due to seasonal flow fluctuations, blending, flood conditions and the impacts of drought. However, the long term salinity of surface water sources will be relatively constant.

4.1.1 Colorado River Water (CAP)

The average TDS concentration established by the Federal government for Colorado River at Parker Dam and thus the CAP is 650 milligrams per liter (mg/L) (CASS, 2003). This concentration is less than the limit of 747 mg/L established in 1972 for the Colorado River at Parker as a part of the numeric salinity control standards. The Salinity Load Flow Chart calculated the CAP imports 1,322,764 tons of salts into the Central Arizona area annually, including 661,382 tons into the Phoenix AMA, based on an average salinity of 650 mg/L. If the TDS increased to the numeric standard limit of 747 mg/L, the Central Arizona salinity load increases to 1,520,161 tons representing 197,397 additional tons of salinity loading into Central Arizona. The salinity load in the Phoenix AMA is 760,080 tons representing and an increased salinity load of 98,698 tons.

The average annual salinity load associated with the CAP entering into the Pinal was calculated in CASS Phase I to equal 298,400 tons. In the Tucson AMA the projected CAP salt load is 65,000 tons in 2000 but due to increasing CAP use over time, the load will increase to 191,000 tons by 2015 (CASS,2003). In the Tucson and Pinal AMAs, CAP water is the only surface water source available. This is why the focus of this memorandum is the Phoenix AMA; it has a greater number of water sources.

4.1.2 Agua Fria River Water

The Agua Fria River represents a small quantity of water, about 50,000 acre-feet per year, entering the Phoenix AMA. Due to the nature of the tributary watershed, the TDS concentration is not expected to vary significantly. The primary salinity impact will be small changes in the salinity load associated with inflow quantity changes. The Agua Fria flow and salinity load impacts on the combined Agua Fria River and Colorado River are also insignificant. This was confirmed using the Salt Loading Flow Chart. If the Agua Fria flow decreased from 0.05 million acre-feet to 0.01 million acre-feet, the combined TDS of the water sources increases from 634 mg/L to 647 mg/L. This is not a significant change.

4.1.3 Salt River Water

The salinity of the Salt River varies based on the quantity of flow entering the Salt River reservoir system due to the salt springs located in the headwaters. As the total Salt River flow decreases, the salt springs inflow constitutes a greater proportion of the total flow and thus there is a corresponding increase in the TDS. CASS evaluated the median salinity of the Salt River, measured at Stewart Mountain Dam, and calculated a median TDS concentration of 580 mg/L (Bur. Rec., 2003). Stewart Mountain Dam is a location upstream of where the Verde River joins the Salt River and is upstream of Granite Reef Diversion dam where CAP water is added to the combined flow of the Salt and Verde Rivers and is diverted by Salt River Project (SRP).

Dr. Gregg Elliot at SRP was contacted to verify the TDS concentration of the Salt River at Stewart Mountain Dam in a high flow year and drought year. Dr. Elliott reported the TDS was about 500 mg/L in 1993 which was a high flow year and was about 980 mg/L in 2002 which was a drought year.

The salinity load is a function of the TDS concentration and the quantity of flow. The United States Geological Survey (USGS) water data website was researched to verify the quantity of flow gaged in 1992 and 2002 at the gage below Stewart Mountain Dam on the Salt River. In 1993 the mean flow was 4,501 cubic feet per second (cfs) which is equal to an annual flow of 3,260,000 acre-feet. In 2002 the mean flow was 416 cfs which is equal to an annual flow of 300,000 acre-feet per year.

The following table presents the TDS and salinity loads associated with median, flood and drought conditions in the Salt River.

TDS in mg/L	Flow Condition	Flow in Acre-feet	Salinity Load in Tons	Deviation from Average
580	Median	540,000	424,912	---
500	Flood	3,260,000	2,211,389	1,786,477 tons increase
980	Drought	300,000	398,864	26,048 tons decrease

This analysis confirms the salinity load into the Phoenix AMA area during drought is less than during median flow periods. Even though the TDS concentration is much greater during a drought the limited quantity of flow results in less tons of salinity load. During floods the opposite is true. The greater volume of flow results in a greater salinity load entering the Phoenix AMA. However, during periods of flood a majority of the Salt River flow passes through the

Phoenix AMA and carries this additional salt load downstream and out of the area. The volume of flood water and associated salinity load varies greatly depending on the amount of available storage in the Salt River system reservoirs, the duration of flood flow and the volume of flood flow. The salinity load associated with the median and drought conditions is more significant than the flood conditions because the salinity load associated with median and drought flows remains in the Phoenix AMA.

4.1.4 Verde River Water

The Verde River is much like the Agua Fria River when evaluating salt loading. The watershed is stable and does not contain salt springs like the Salt River. The median TDS concentration of the Verde River is 270 mg/L. The principal impact to the Phoenix AMA water supply will be when the flow is reduced or increased and there is a corresponding change in the total salinity load.

4.1.5 Combined Salt and Verde Rivers

The Verde River joins the Salt River upstream of the SRP Granite Reef Diversion Dam. The combined flow is then delivered via a series of canals to water users on the north and south sides of the Salt River. Because the TDS concentration of the Salt River can vary, the following is a projection of the TDS concentration and salinity load of the combined flows at the Granite Reef Diversion Dam.

Salt River TDS	Salt River Flow Condition	Salt & Verde Rivers TDS	Salinity Load in Tons	Deviation from Average
580	Median	502	523,814	---
500	Flood	508	2,269,591	1,745,777 tons increase
980	Drought	678	497,766	26,048 tons decrease

This analysis verifies the combined salinity load of the Salt River and Verde River at Granite Reef Dam does not vary significantly when comparing median and drought flow conditions in the Salt River. The greatest variation is in the TDS concentration. The average TDS concentration difference between the median and flood conditions is not significant but the salinity load is much greater. The load in median and drought conditions is more significant because the salinity load remains in the Phoenix AMA while most of the salinity load during flood periods passes through the AMA.

4.1.6 Surface Water Sources Long Term Salinity Impacts

A purpose of this study is to project the potential long term regional salinity impacts. The TDS concentration of the surface water sources can and often does vary annually. However, long term projections of salt loading can be calculated associated with variations in surface water TDS. The

Salinity Load Flow Chart was used to calculate the theoretical annual salinity load remaining in the Phoenix AMA assuming the TDS remained constant during the 10-year and 25-year projection periods. The 10-year time period was selected because the flood conditions in the Salt River system circa 1980 was almost a 10-year period and the current drought is defined as a 7 to 9 year period (depending on the information source). The 25-year period was selected as a long term projection based on input from the CASS Planning Technical Committee. The purpose of the following table is to present the magnitude of the potential impacts and to identify which surface water source has the greatest impact on salinity loading in the Phoenix AMA.

Water Source	TDS Concentration	Annual Salinity Load Remaining in Phoenix AMA	10-year Salinity Load Remaining in Phoenix AMA*	25-year Salinity Load Remaining in Phoenix AMA*
CAP Average TDS	650 mg/L	1,212,330 tons	12,123,300 tons	30,308,250 tons
CAP Salinity Standard TDS	747 mg/L	1,311,028 tons	13,110,280 tons	32,775,700 tons
Salt River Median	580 mg/L	1,212,330 tons	12,123,300 tons	30,308,250 tons
Salt River Flood	500 mg/L	2,998,807 tons	29,988,070 tons	74,970,175 tons
Salt River Drought	980 mg/L	1,186,282 tons	11,862,820 tons	29,657,050 tons
CAP Salinity Standard TDS and Salt River Drought	747 mg/L CAP and 980 mg/L Salt River	1,284,980 tons	12,849,800 tons	32,124,500 tons

* Shown for comparison only.

If the conditions on the Colorado River resulted in an increase in TDS to the numeric standard, the calculation projects an additional 1 million tons of salinity would remain in the Phoenix AMA after 10 years. This calculation is based on a constant CAP delivery with no changes in flow volume. However, drought conditions on the Salt River system can increase the TDS concentration and reduce the flow volume thus reducing the projected salinity load. Based on the drought condition in the Salt River system there is a net decrease of about 260,480 tons in the Phoenix AMA salinity load over the 10 year period. This data verifies the CAP TDS impacts have a more significant salinity load impact on the Phoenix AMA than does the drought impacts related to the Salt River system.

This data also projects the salinity loading impacts associated with flood conditions on the Salt River. These calculations are included for reference because unlike a drought, flood conditions would not be expected to last for 10 years or more.

The projections for the 25-year period follow the same trends as the 10-year projections. The difference is in the amount of total changes.

4.2 Groundwater

Groundwater is used in public water supply systems to meet residential, commercial and industrial demands and also for agricultural, turf and golf course irrigation (Figure 1). Groundwater TDS concentrations vary throughout the Central Arizona area and can be in the range of 250 mg/L to more than 3,000 mg/L. This is a much greater variation than occurs in surface water. In this memorandum the TDS and salinity loads are expressed based on regional conditions rather than site specific conditions.

Groundwater quality in Central Arizona basins is impacted by the quality of natural recharge, groundwater inflow from other groundwater basins, local geologic conditions, artificial recharge and agricultural leaching,

The quantity of natural recharge in Central Arizona is limited and in all the Central Arizona basins such as in the Phoenix, Pinal and Tucson AMAs, groundwater pumping greatly exceeds the quantity of natural recharge. While the rainfall generating the runoff which may recharge the aquifer units is usually of very high quality, the quality of the natural recharge will vary depending on the geologic formations the runoff crosses. In the majority of the locations, natural recharge water is high quality water. Due to the quantity of natural recharge, any TDS and salinity load changes associated with natural recharge will be small and occur over long periods of time.

Groundwater inflow from adjacent basins can impact water quality. The projected average salinity load entering the Tucson AMA from the Santa Cruz AMA and other sub-basins in the Tucson AMA is about 5,000 tons per year. The average load entering the Pinal AMA from the Tucson AMA and the other sub-basins in the Pinal AMA is about 68,300 tons per year (CASS, 2003). The average load entering the Phoenix AMA from the Pinal AMA and other sub-basins is 36,902 tons per year. As with natural recharge, any TDS and salinity loading changes will be small and will occur over long periods of time.

Local geologic features such as the Luke Salt Dome in the western portion of the Phoenix AMA can influence local groundwater quality. Wells adjacent to the salt dome have reported TDS concentrations of 40,000 mg/L. These local impacts are diluted as the groundwater moves and blends with other groundwater in the aquifer units.

Regional groundwater quality impacts associated with agricultural leaching and artificial recharge will be assessed in following sections of the Task 200 memorandum where the impacts will be calculated using the Salinity Load Flow Chart.

Groundwater is used for different purposes based on the quality. Groundwater used in the Phoenix AMA in the public water supply system was projected to have an average TDS concentration of 740 mg/l while the groundwater used for agricultural irrigation was calculated to have an average TDS concentration of 2,100 mg/L (CASS, 2003). Crops can tolerate a greater TDS concentration than the general public will accept as a part of the drinking water supply. In the Tucson AMA, groundwater used in the public water supply system averages 265 mg/L while the groundwater used for agricultural supply averages 450 mg/L.

Groundwater pumping does not increase the TDS in the aquifer or the salinity load but rather is a redistribution of the salinity load. Figure 1 shows groundwater pumping takes the salinity load from the aquifer and through the public water system which distributes groundwater to uses where the salinity load is added to the soil, the reclaimed water supply, or is placed back in the aquifer through the artificial recharge of reclaimed water. In other cases the groundwater salinity is recycled back to the aquifer due to agricultural leaching.

4.3 Reclaimed Water

Reclaimed water is used to meet some commercial and industrial demands, for the irrigation of agricultural crops, turf and golf courses and for artificial recharge. Wastewater discharges from residential, commercial and industrial uses are conveyed through the sewer system to wastewater treatment plants (WWTP) and water reclamation plants (WRP) where the water is treated and reclaimed water produced (Figure 1). The average reclaimed water TDS concentration calculated for the reclaimed water in the Phoenix AMA was 890 mg/L and for the Tucson AMA was 525 mg/L (CASS, 2003).

The interrelationship of the water sources and water uses to the regional reclaimed water supply is shown on Figure 2. A change in the TDS concentration of CAP or Salt River water will have wide spread impacts throughout the regional water supply impacting water uses and eventually the reclaimed water quality. The following table projects the impacts to the regional reclaimed water supply if the CAP TDS increased to the numeric standard of 747 mg/L and the Salt River TDS variations associated with median, flood and drought conditions. The TDS concentration associated with flood conditions in the Salt River system is more important than the associated salinity loading because a portion of the flood water with the reduced TDS concentration is diverted for use and will impact the regional reclaimed water TDS concentration. The table also projects the reclaimed water TDS impacts should the CAP TDS be at the numeric standard and the Salt River is in drought condition.

Water Source	TDS Concentration	Regional TDS Reclaimed Water
CAP Average TDS	650 mg/L	859 mg/L
CAP Salinity Standard TDS	747 mg/L	897 mg/L
Salt River Median	580 mg/L	859 mg/L
Salt River Flood	500 mg/L	829 mg/L
Salt River Drought	980 mg/L	926 mg/L
CAP Salinity Standard TDS and Salt River Drought	747 mg/L CAP and 980 mg/L Salt River	970 mg/L

The TDS concentration and salinity load associated with reclaimed water varies due to the proportion of the water sources used in the public water supply system tributary to the WWTP and WRP and TDS increases associated with the uses. Staff at several WWTPs and WRPs were contacted to verify the average TDS concentration in the reclaimed water produced at their facilities. These facilities were selected to provide a range of TDS concentrations based on the initial sources of water contributing wastewater to the plants.

WWTP or WRP	Principal Water Sources	Average TDS Concentration	Maximum TDS Concentration
Fountain Hills Sanitary District	CAP	900 mg/L	1,300 mg/L
23rd Avenue WWTP	CAP, SRP & groundwater	1,022 mg/L	1,380 mg/L in 2004
91st Avenue WWTP	CAP, SRP & groundwater	1,040 mg/L	1,400 mg/L in 2004
Cave Creek WRP	CAP & groundwater	1,143 mg/L	1,250 mg/L in 2004

The data for 23rd Avenue, 91st Avenue and Cave Creek are based on 24-hour composite samples rather than one sample collected at a specific time.

5.0 Future Salinity Impacts

The projected future salinity impacts are related to the retention of salinity within the Central Arizona area and how the retention of salinity may influence the water supplies and the potential uses of these supplies. Figure 1 maps the path of water and associated salinity showing uses where the salinity potentially increases and where salinity can accumulate.

Surface water supplies may have seasonal and annual changes in TDS concentrations but these are caused by conditions outside of the Central Arizona area. The primary salinity load impact is caused by importing of surface water and the associated salinity load into the Central Arizona area. In the Phoenix AMA, Figure 2 projects surface water imports about 77 percent of the salinity load while 33 percent is added as a part of the use of the water.

Reclaimed water and a portion of the pumped groundwater recycle the salinity and do not represent accumulation points. Interior residential, commercial and industrial water use can concentrate the salinity load contained in the source water and these uses can increase the TDS concentration through the addition of additional compounds to the wastewater stream. The reclaimed water and associated salinity load is recycled when the water is used for irrigation, artificial groundwater recharge and some commercial or industrial uses (Figure 1). A portion of the pumped groundwater is used for residential, commercial and industrial interior uses and follows the same path as surface water through the reclaimed water system. When reclaimed water is used for artificial groundwater recharge, some of the salinity load initially associated with groundwater is returned to the aquifer where it can be pumped again and further recycled.

Figure 1 shows there are several salinity accumulation points including the soil horizon, aquifers and some industrial uses. Non-agricultural irrigation of turf and landscaping usually does not include a water allotment for leaching to flush the salinity through the soil to below the root zones. In this case salinity will accumulate in the soils.

Aquifers are also accumulation points. Agricultural irrigation does include water allotments for leaching and the salinity associated with the irrigation water is flushed down to the groundwater. The result is increasing TDS concentrations in the aquifer units and in the pumped groundwater.

In some cases the accumulation of salinity removes the TDS from the Central Arizona system. Reclaimed water provided to the Palo Verde Nuclear Power Plant is used for cooling water and eventually discharged to evaporation ponds where the minerals precipitated out of solution due to the increased concentration.

The future impacts associated with the recycling and accumulation of salinity in soils are assessed in the following sections.

6.0 Salinity Limits and Tolerances

A goal of this white paper is to assess potential future impacts associated with TDS concentration increases and salinity accumulation. The initial step in these assessments is to define the TDS limits associated with specific uses.

6.1 Vegetation Salinity Tolerances

The TDS concentration limits associated with vegetation vary because food, forage and landscaping plants have different salinity tolerances. The terms used to express plant tolerance are sensitive, moderately sensitive, moderately tolerant and tolerant. These are general terms. Water is classified based on the TDS concentration and the Sodium Adsorption Ratio, calculated using the ratio of sodium, calcium and magnesium concentrations in the water. This white paper will assess the salinity hazard of water based on the TDS concentration.

The TDS concentration is expressed as mg/L or as millimhos per centimeter (mmhos/cm). TDS is also identified in calculations as the electroconductivity of the water (ECw). The following is a general classification of water based on the TDS concentration (Bouwer, 1978).

Potential Plant Toxicity	TDS in mg/L	TDS in mmhos/cm
None	Less than 480	Less than 0.75
Moderate	480 to 1920	0.75 to 3.0
Severe	Greater than 1920	Greater than 3.0

The relationship of the TDS of the surface water, groundwater and reclaimed water sources to the potential plant toxicity is presented on Figure 3. This data shows the Agua Fria and Verde River are in the no problem range while the groundwater used for irrigation can be in the severe problem range. The remainder of the water sources available in Central Arizona are in the moderate problem range.

Table 4 compares the reclaimed water salinity presented in Section 4.3 to the potential plant toxicity. This information shows the reclaimed water is in the moderate problem range. The average daily TDS concentrations would have to increase significantly to pose a severe problem.

The suitability of a water source for irrigation is based in part on the TDS concentration of the water and also the salinity of the soil. Water with a higher TDS concentration may not be appropriate for irrigation in poorly drained or saline soils without making an allowance for leaching to flush the salinity below the root zone. Soil salinity is classified based on the mmhos/cm measured in the soil saturated extract solution measured in a laboratory. The soil salinity is the electroconductivity of the soil saturated extract (ECe). The following is a general classification of ECe and plant response (Kotuby-Amacher, et. al., 1997).

ECe mmhos/cm measurement	Plant response
0 to 2	Mostly negligible
2 to 4	Growth of sensitive plants may be restricted
4 to 8	Growth of many plants restricted
8 to 16	Only tolerant plants can grow satisfactorily
Greater than 16	Only a few, very tolerant plants grow satisfactorily

The plant response does not mean when the tolerance ECe is exceeded the plant will die. The impacts of ECe and ECw increases results in plant stress and in the case of commercial agriculture, a reduction in yield per acre. For example, alfalfa is a common forage crop grown in Central Arizona. It has a tolerance ECe of 2.0. When the ECe increases to 3.4 mmhos/cm there is a 10 percent yield reduction. When the ECe is 5.4 mmhos/cm the reduction is 25 percent and at 8.8 mmhos/cm, the reduction is 50 percent.

Table 6-1 presents the soil associations in the Phoenix AMA area and the ECe classifications. The soil data is from Soil Conservation Service reports. This table verifies most of the soils are in the mostly negligible to growth of sensitive plants may be restricted plant response categories when the soils are assessed on a regional basis. However, the local soil conditions reflecting the maximum typical ECe includes the full range of plant responses.

The formulae and other ECe and ECw calculations are outlined in the CASS Phase I Technical Appendix A white paper. The following references provide additional background information to assess the impacts of increasing TDS concentration in the water supplies and increasing salinity in the soil. These references can be researched on the internet.

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6.2 Commercial and Industrial Requirements

Increases in the TDS concentrations in water sources can influence the suitability of the water to meet the commercial and industrial use requirements. In the CASS Phase I appendices there are several white papers outlining the water quality needs for commercial and industrial uses. Figure 1 shows the commercial and industrial uses can receive surface water, groundwater and reclaimed water. If the commercial or industrial user is provided potable water, then the potential for future TDS concentration increases to impact their operations is very slight. If the water user is provided groundwater or reclaimed water, then there may be impacts if the TDS concentration increases in these water sources in the future.

The Future With No Action Alternative analyses has shown there may be impacts to the suitability of reclaimed water for agricultural uses if the TDS increases to the concentration where there may be impacts on plant growth. This is also true for the turf related commercial operations such as golf courses. Industrial operations where the groundwater or reclaimed water is used for cooling or other industrial purposes may have increased costs to reduce the TDS concentration. These cost increases could also include chemical to control scale formation and increased water costs if cooling water salinity prevents multiple passes through the cooling towers. This is also outlined in the CASS Phase I appendices.

6.3 Potable Water Uses

Many communities use a TDS target of 500 mg/L for potable water; however as the data shows several surface water sources and groundwater can and often does exceed this goal. In Tucson, the TDS goal is lower than the 500 mg/L. There is no maximum contaminant level (MCL) established for TDS only a secondary standard of 500 mg/L. The Future With No Action

Alternative analyses show the water source that may be subjected to long-term TDS increases in the future is groundwater. If the TDS concentration in groundwater increases to the amount where it impacts the palatability of the groundwater, water providers will have to treat the groundwater, blend the groundwater with a water sources with a lesser TDS concentration or stop pumping from that well.

The public may desire water with a lower TDS concentration than is in the water delivered to their homes. This desire to reduce the TDS, especially the scale forming minerals such as calcium, is what drives the water softener market. Potable standards established by Federal and State agencies are different from palatable needs of the public. The water provided by municipal and investor owned water utilities must meet the potable standards but the public may desire water treatment to enhance the quality palatability. The then becomes a needs verses wants issue for treatment.

If the TDS reduction technologies are being considered because there is a goal to reduce the TDS concentration because it is wanted rather than needed, then water resources losses associated with the treatment concentrate reject may be a significant impact. The concentrate reject water is difficult and expensive to recover and represents a reduction in the overall water resources. The loss of water may require development of new or expanded water supplies, may require additional pumping of groundwater from aquifers and may increase the demand on existing water supplies to make up for the shortfall.

6.4 Groundwater Recharge

Figure 1 shows groundwater can be recharged naturally by precipitation and stream flow infiltration and also due to infiltration and leaching associated with exterior irrigation and farming and due to artificial recharge. Groundwater salinity can be impacted by leaching and artificial recharge. As described in Section 4.2, the TDS concentration in groundwater varies throughout Central Arizona. In almost all instances, leaching water will increase the TDS concentration in groundwater. Artificial recharge using surface water or reclaimed water may have either a negative or positive impact on the groundwater quality depending on the TDS concentration of the groundwater and the recharge water. In locations such as the southwest portion of the Phoenix area, the groundwater contains very high TDS concentrations and surface water or reclaimed water recharge will improve the overall groundwater quality. In locations such as Tucson where the groundwater has a very low TDS concentration, recharge using CAP water and reclaimed water will increase the overall TDS concentration of the groundwater. Most of the Central Arizona areas will be somewhere between these extremes and site specific conditions will dictate if groundwater recharge will improve or degrade groundwater quality.

There are no TDS MCL standards for groundwater only a secondary standard of 500 mg/L. Arizona can regulate the recharge of water sources which map produce a degradation of groundwater quality as a part of the Aquifer Protection Permit program. The Future With No Action Alternative analyses indicates recharging surface water may have an impact on some groundwater sources like in Tucson but generally surface water sources will not continue to have TDS concentration increases in the future. Reclaimed water may be subject to increasing TDS concentrations in the future and this may result in the ability to use reclaimed water as a source for groundwater recharge. If the TDS concentration in reclaimed water prevents use for groundwater recharge, this could impact the long term water budget and water supply in the future because other water sources may need to be diverted or developed to replace reclaimed water for recharge.

7.0 Summary

The Future With No Action Alternative analyses determined:

- The TDS concentration in surface water may vary depending on drought, flood or normal conditions in the watershed but the overall TDS concentration will remain within a concentration range defined for each surface water source.
- TDS minerals will accumulate over time in the soil as a result of exterior water use and agricultural irrigation. This soil salinity increase will impact the ECe of the soil and impact the growth pattern of vegetation and may require additional irrigation water use to compensate for the increased ECe. The impacts of soil salinity increases and the timing of the impacts are site specific based on the soil types, current ECe and TDS of water used for irrigation.
- TDS concentration increases in water used for irrigation may impact the suitability for use on certain crops. The degree of impact will depend on the salt tolerance of the crop, the ECw of the water and the ECe of the so
- il. The amount of impact and the timing of when impacts may occur are site specific considerations.
- TDS concentration increases in water used for groundwater recharge may result in an overall degradation of groundwater quality in many areas of Central Arizona. In some instances, reclaimed water may not meet acceptable limits for use as a recharge water source. This is also a site specific issue because reclaimed water quality is influence by the quality of the water used and discharged to the sewers and the residential, commercial and industrial interior water uses which add TDS minerals to the water prior to discharging to the sewers.
- In some cases, the TDS of water may not need treatment to control or reduce the TDS concentration but the treatment is initiated because it is what the public wants to increase the palatability of the water.
- In the future, increases in the TDS concentration in groundwater and reclaimed water may result in the water not meeting the quality required for some specific uses. In these cases, if treatment to reduce or control the TDS concentration is not applied the water may not be suitable for the intended use. In such a case, either the use must be discontinued or an alternative water source must be secured. This means the TDS concentration is not only a water quality issue but also become a water resources issue because the overall water supply available for a region in Central Arizona may be reduced.

11.0 References Cited

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